namely, that their degree of disintegration would continue the same. There could be no more chemical combination in the sun, if thus retaining all its heat, than in the rare matter of space. For chemical condensation to take place the heat contents must be reduced. An equal degree of absolute heat signifies an equal motive vigour of particles, and it is this motive vigour which enables them to resist chemical attraction. It may be supposed, however, that in dense matter the chemical attraction would be more effective from its increased energy through contiguity. Yet this is an erroneous idea; there is no real greater contiguity between the particles of dense than of rare matter. In both cases, the particles are brought incessantly into absolute contact through their vibrations. The number of contacts of dense as compared with rare matter may be millions to one, but that can have no effect upon the result. If the chemical vigour be stronger than the vibratory vigour it will overcome it in the contact; if it be weaker it will fail to overcome it, and a more frequent repetition of contacts cannot materially aid this result.

Thus all substances of equal absolute heat must be equal in degree of chemical integration, whatever their degrees of tensity or condensation. But the assumed equality of absolute heat cannot continue between dense and rare gases. The sensible heat of the dense gas tends to radiate out into the chilled rare gas. A constant and vigorous effort to equalise temperatures takes place. With every outflow of radiant heat from a sphere into space the absolute heat of the particles of the sphere decreases, that of the rare matter of space increases. The absolute heat contents grow more unequal with every step towards equalisation of temperatures. Consequently a variation in chemical condition arises. The loss of heat by the sun, for instance, reduces the vibratory resistance to attraction, and with every such loss chemical molecules of greater complexity are formed. This heat is radiated into space. Probably some portion of this radiant heat is arrested and becomes local heat in the matter of space. If so the heat vigour of this matter increases, disintegration must ensue, and the increasing chemical condensation in the sun must be matched by an increasing chemical disintegration in outer matter.

During the myriad years of solar condensation, this process of heat-outflow has been continuous, so that now, despite its great excess of temperature, the absolute heat of solar matter must be far below that of an equal mass of the matter of outer space. Can the heat thus lost by the sun be recovered? If it could, the solar heat emissions might continue indefinitely. Dr. Siemens' hypothesis offers a method of recovery. If the matter of outer space is drawn into the solar atmosphere by such a polar inflow as he supposes, and subjected to the vigorous condensing influence of solar gravity, its volume must be very greatly decreased, and much of its latent heat become sensible. And as its absolute heat-contents are far in excess of those of solar matter, the result of such condensation must be a high degree of temperature, and a continual replacement of the radiated heat of the sun. Without any chemical integration taking place in this inflowing matter, the solar temperature may be kept up by its mere condensation, and by rendering available its great excess of absolute heat. With chemical integration, and the consequent much greater condensation, of course the heat-yielding effect must be much more considerable.

This inflow of outer matter to the sun is, in Dr. Siemens' hypothesis, rendered possible by a continuous outflow of solar matter to outer space, thus carrying substance of low heat energy to be mingled with the rarefied exterior matter, whose high heat energy is thereby somewhat reduced. Such a process, however, has in it something of the flavour of perpetual motion. The sun is giving and taking, and its receptions may be equal to its emissions. It would thus constitute a machine yielding power to, and regaining power—to be again yielded—from the same substance. Yet there is another element in the case, which relieves it of this suspicious perpetual motion flavour. If the sun is constantly flinging off rare matter at a tangent from its upper atmosphere, there must be a reaction upon the rotatory energy of the solar sphere. It must be gradually losing its energy of rotation, with extreme slowness, of course, since the weight thrown off is very slight, but in time the effect cannot but become a marked one, and perhaps this loss of solar energy may be the ultimate source of the new heat obtained by such a process. We may conceive of a like process taking place, to a less marked extent, in the large and rapidly rotating planets, such as Jupiter. CHARLES MORRIS

Philadelphia, U.S.

UNDER this title Dr. C. W. Siemens, on March 2, presented to the Royal Society a paper, which is published in NATURE, vol. xxv. p. 440. Therein, after noticing the hypotheses proposed by Meyer, Helmholtz, and Sir William Thomson, to explain the maintenance of solar heat, he endeavours to show how the energy apparently lost by radiation from the sun into space, may be gathered up and restored to the centre of our system. This he conceives to be effected through the intervention of attenuated matter diffused throughout space, which is the recipient of the radiated energy, and is continuously absorbed and again reflected by the centrifugal action of the sun itself. The matter diffused through space he supposes to include oxygen and nitrogen, hydrogen, aqueous vapour, and carbon compounds, besides solid materials which are probably exhalations from the sun, and constitute the so-called cosmic dust.[1]

In support of this view of an interstellary nature Dr. Siemens cites Grove and Mattieu Williams, among others, but does not seem aware that its agency in gathering up and restoring to the sun its lost radiant energy, has been maintained by these writers. Sir William Grove, in his address as President of the British Association in 1866, attempted to find in this interstellar matter (whose nature and relations to our atmosphere he had already considered in 1843, in his celebrated essay on "The Correlation of Forces"), a source of solar heat, inasmuch as the sun "may condense gaseous matters as it travels in space, and so heat may be produced." This same view suggests the title of "The Fuel of the Sun," by Mattieu Williams, a book published in 1860, the argument of which, as briefly resumed by me in an essay on "The Chemical and Geological Relations of the Atmosphere," in the *American Journal of Science* for May, 1880, is as follows:—

"The solar heat, according to Williams, is maintained by the sun's condensation of the attenuated matter everywhere encountered by that body in its motion through interstellar space. The irregular movements impressed upon the sun by the varying attractions of the planets, stirring up and intermingling the different strata of the solar atmosphere, and producing the great perturbations therein, of which the telescope affords evidence, are, in his hypothesis, the efficient agents in the process. The diffused matter or ether, which is the recipient of the heat-radiations of the universe, is thereby drawn into the depths of the solar mass; repelling thence the previously condensed and thermally-exhausted ether, it becomes compressed and gives up its heat, to be, in turn, itself driven out in a rarefied and cooled state, and to absorb a fresh supply of heat, which he supposes to be, in this way, taken up by the ether, and again concentrated and redistributed by the suns of the universe."

The astronomer must judge between the different views of the mechanism of what may be called the process of solar respiration in this hypothesis, as put forward by Siemens and Williams respectively. We may call attention in this connection to Newton's "Principia," book iii., proposition 12.

The views of Grove and of Williams, cited in my paper of 1880, are farther considered in an essay on "Celestial Chemistry from the time of Newton," read by me in November, 1881, before the Philosophical Society of Cambridge, and reprinted from its *Proceedings* both in the *Chemical News* and the *American Journal of Science* for February, 1882. A perusal of this paper, to which Dr. Siemens alludes, will show that Sir Isaac Newton 200 years ago conceived the existence of an interstellar ether made up in part from emanations and exhalations from the atmospheres of the earth, the planets, and the sun, and from comets. He further conjectured this interstellary medium to contain "the material principle of life" and "the food of sun and planets," furnishing "the solary fuel," and being copiously absorbed by the sun "to conserve his shining." The relations of this interstellary matter to terrestrial life I have endeavoured to set forth in the paper just noticed. In connection with Sir William Thomson's calculation of the density of the luminiferous medium therein mentioned, the reader is referred to a recent examination of the subject by P. Glan, in the *Annalen der Physik und Chemie*, No. viii. 1879, in which he concludes that the lower limit of density would be more than 7000 times greater than that calculated by Thomson.

[1] In a paper on the subject of an interstellar medium, read by me before the French Academy of Sciences (*Comptes Rendus*, September 23, 1878, page 453), I spoke of it as affording, in accordance with the ideas of Newton and of Grove, a means of material communication between celestial bodies and added: "Cette théorie d'une échange universelle me paraissait fournir une explication de l'origine des poussières cosmiques."

Dr. Siemens has, in his paper, further suggested that solar radiation may effect the dissociation in interstellar space of the compounds of oxygen with carbon and with hydrogen, so that these elements may reach the sun in an uncombined state, and there be burned. He would thus make the sun not only a compressing-engine, but a furnace. While such a dissociation in outer space is not impossible, it is to be said that a preliminary decomposition, followed by reunion in the solar sphere, would in no way augment the ultimate calorific effect of compression there. The elements in the act of dissociation in space would absorb just as much radiant energy as would be set free by their subsequent combination, so that, whether the solar radiations are expended in heating or in dissociating the diffused matter, the final result in the sun would be the same. It may be further remarked, that from what we know of solar chemistry, dissociation of aqueous vapour and of carbonic dioxide is more likely to take place in the sun itself than in the cold regions of outer space.

While, therefore, his suggested addition to the hypothesis seems, if not untenable, unnecessary, we are grateful to Dr. Siemens for again bringing before us the grand conception which dawned upon the mind of Newton, but has found its fuller expression in our own day, and, as I have endeavoured to show in the papers already noticed, gives us the elements of a rational Physiology of the Universe. T. STERRY HUNT

Montreal, Canada, April 3

THE two preceding letters by American men of science of well-known position, grant one of the three postulates upon which I grounded my solar plan, that of space filled with attenuated matter; they do not object to the second, and all-important one of the equatorial outflowing current; but they call in question the necessity of the third, that of dissociation of attenuated matter in space by means of arrested solar energy. Both my critics think dissociation in space unnecessary for the maintenance of solar energy, or as Dr. Sterry Hunt very clearly puts it: "Whether the solar radiations are expended in *heating* or in *dissociating* the diffused matter, the final result in the sun would be the same."

I would be disposed to agree with this dictum if taken as an abstract proposition, but I do not think that my critics can have subjected their view to calculation, the keystone without which the arch of speculation cannot be considered as secure. We know by experimental evidence that stellar space, and the matter filling it, are intensely cold, as proved by the winter-temperature of the polar regions; moreover water exposed even in the tropics to free radiation while insulated from the warm earth, freezes to a considerable thickness during a single night.

Let us suppose that the attenuated matter in space has a temperature of 160° on the absolute scale (being 114° below the freezing-point of water), and that it is 3000 times more rarefied than when it reaches by adiabatic comparison the solar photosphere. The rise of temperature due to this compression must be according to Rankine's well-known formula—

$$\tau_2 = \tau_1\left(\frac{p_2}{p_1}\right)^{\frac{\gamma - 1}{\gamma}} = \cdot 29 = 1632^\circ \text{ absolute},$$

and this would make the solar photosphere 1358° on the Centigrade scale; this temperature is quite inadequate to produce the solar luminosity, which must require one equalling, though probably not exceeding that of the electric arc.

But assuming a compression of the attenuated atmosphere up to the photospheric density (which according to most authorities does not exceed terrestrial atmospheric density), there would still remain the predicament that although a higher maximum temperature could be reached by compression, very little of the heat due to it could be spared for the purpose of radiation, without sacrificing the possibility of disposing of the refrigerated gases again into space. The refrigerated gases would obey the law of solar gravitation to a much greater extent than the heated incoming gases, and would certainly not pass away into space, unless acted upon by a considerable extraneous force. The mere passage of the solar orb through space at a majestic pace which does not exceed one quarter of our orbital velocity, could not possibly produce such a result, and even the fan action advocated in my paper would fail to work in opposition to a large determining influence of solar gravitation.

These conditions are entirely changed if we assume, in addition to adiabatic compression and re-expansion, a further source of heat such as is produced in combustion. One pound of hydrogen develops in burning about 60,000 heat units, and one pound of marsh gas 24,000 heat units; in my article upon this subject, published in the April number of the *Nineteenth Century*, I showed that if only one-twentieth portion of the gases streaming in upon the polar surfaces at the pace of 100 feet a second were combustible gases, they could produce an amount of heat more than sufficient to account for the entire solar radiation as determined by Herschel and Pouillet.

There is no reason for supposing that the instreaming gases would penetrate beyond the solar photosphere; they would flash into combustion whenever their temperature by adiabatic compression had reached the limit of spontaneous ignition without the presence of an igniting solid, a point which, if determined experimentally, would give a clue to the real vapour density of the photosphere; and after reaching the point of dissociation, combustion would continue in the measure of the abstraction of heat by radiation, thus producing a vast accumulation of igneous matter of comparatively low density. This would flow on, in the manner of a floating body, above the denser gases or vapours forming part of the permanent body of the sun, towards the equatorial regions, whence it would be propelled into space at a temperature exceeding to some extent that of the inflowing gases after compression, but before combustion, thus aiding, instead of retarding the supposed solar fan action.

The fan-action itself would be produced, no doubt, at the expense of solar rotation; but, in order to appreciate this retarding influence at its true value, it must be borne in mind that the flow of gases once established has only to be changed in direction; the velocity acquired by the inflowing gases is simply transferred to the outflowing current diminished by an amount of rotative force sufficient to cover frictional retardation. The very interesting leading article in last week's NATURE, regarding the solar observations in America, during the last eclipses, now published for the first time, furnishes an unexpected and most striking corroboration of the solar fan-action which I had ventured to put forward as a necessary consequence of solar rotation in space filled with attenuated matter.

I am well aware that my paper read before the Royal Society does scant justice to those who have devoted much time and ingenuity to the subject of solar physics, and that, moreover, many points of considerable interest connected with the views I advocate have been indicated only, instead of having been fully developed; but, on the whole, I thought it was better to present my views in mere outline before an audience well acquainted with our present information regarding solar physics, and with only half an hour's time at their disposal.

The elaboration of such a subject would necessitate the writing of a book rather than of a paper, and perhaps Dr. Sterry Hunt, who has already done so much to elucidate our present knowledge of solar physics, may be induced to extend his labours in this direction. C. W. SIEMENS

12, Queen Anne's Gate, Westminster, April 26

Silurian Fossils in the North-West Highlands

MY friend, Mr. Hudleston, in his letter on the Silurian fossils in the North-western Highlands, states very clearly a point which at the present time is of the highest importance to all students of the metamorphic rocks. If it can be proved that the Durness limestone, which contains undoubted lower Silurian fossils, is identical with the series in Western Sutherland and Ross, which Mr. Hudleston terms the quartzo-dolomitic, then the so-called "Newer Gneiss" must be more recent than it, and thus must be a metamorphosed representative of some part of the Silurian series. This would prove that very great regional metamorphism has taken place in the latter half of the Palæozoic period; and that its mineral condition will not aid us materially in determining the age of a rock which has once been stratified.

But is this identity proved; and is it certain that the Durness limestone is more ancient than the Newer Gneiss series? I have not myself had the opportunity of investigating the Durness region, though I have examined several specimens of its limestone; and from the condition of these and my knowledge of parallel cases, and of metamorphic rocks in general, do not hesitate to say that I should require very clear stratigraphical evidence before I could believe the Durness limestone to underlie the "Newer Gneiss." The former is no more metamorphic than are several of the Palæozoic limestones; the latter is always considerably, sometimes rather highly, metamorphosed. But in